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THE POET REVEALED: A FUTURE FOR HUMAN-CENTERED DESIGN

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This paper has been reviewed and is approved for publication.

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The paper describes human-centered design technology as it might operate in the future. A "prototype on-screen ergonomic technology" is described in the form of a story. The objective of the paper is to introduce general readers to computer-graphics man-modeling work being done by the Air Force Human Resources Laboratory's Logistics Systems Branch.

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THE POET REVEALED: A FUTURE FOR HUMAN-CENTERED DESIGN

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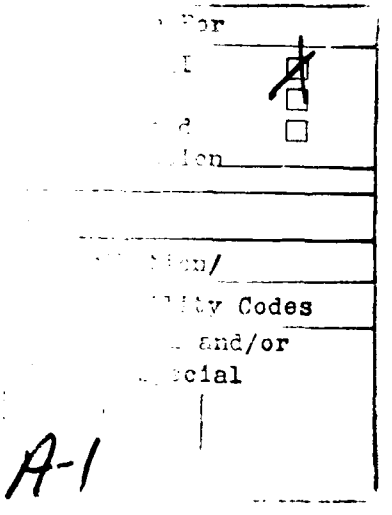

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PREFACE

This paper describes what human-centered design technology might be able to contribute to logistics system engineering in the distant future. The objective is to promote interest in a serious but technically dense topic through a humorous and plain spoken story. No warrant should be implied for the ultimate feasibility of every capability envisioned here, but most of them are being worked on at AFHRL and elsewhere at this moment. Some of the human-modeling capabilities described here are based on the AAMRL/AFHRL "Crew Chief" technology. Others are included in new research by the Logistics Systems Branch under Work Unit 2940-03-05 entitled Design Evaluation for Personnel, Training, and Human Factors (DEPTH), toward whose progress the reader's attention is especially invited.

Somber clouds drape day's last light
The tempest's gloomy shrouds in sight
Waves to rumble, winds to roar
Seastorm's violence rolls ashore

- Eboly

Kate May was driving back to her office when the downpour began. She could barely make out the Stone Harbor exit as she inched along the Parkway. She hopscotched over the rain puddles in the deserted parking lot and rushed through the door of Pepamar Technologies. Her clothes had gotten only a little damp. "Next time an umbrella. Could have ruined my new jersey," she muttered to herself as she opened her office door and switched on the computer workstation.

A disembodied voice is heard. "Good morning Miss May."

"You mean good evening, don't you? Bonehead computer. Besides, it's not so good. It's raining cats and dogs tonight."

"Cannot parse... wait... user input post scan... analysis... undefined folk idiom... probable hackneyed metaphor... retry ... Good morning Miss May."

Annoyed now, Kate reprogrammed the computer's clock. It flashed "8:40 P.M. June 18, 2001." Then she decided to toggle from automatic speech synthesis mode to manual keypad/mouse mode for person/machine interaction. A glitch like this one would mar the demonstration of the **P**rototype **O**n-Screen **E**rgonomic **T**echnology. Kate had returned to the office that night to run the **POET** through its verses one last time. She wanted everything to be perfect for the Critical Design Review (CDR) the next afternoon, and she was naturally a little nervous.

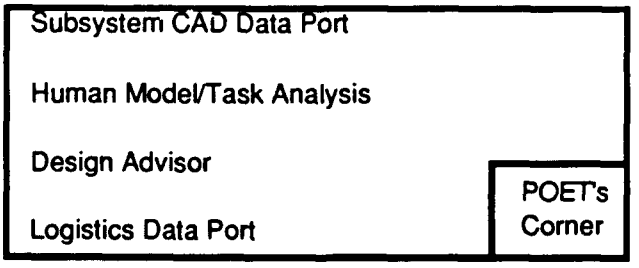
Six months earlier, Pepamar had received a subcontract from Orchard Industries to develop the complete Personnel Subsystem for the new Macintosh Air Vehicle, or MAV. The MAV was competing against the Trump Air prototype, The Marla, to win the contract to upgrade the USAF Advanced Technical Fighter. Orchard's MAV was leveraged heavily on Pepamar's POET human-model to edge out The Marla in the upcoming logistics simulation trials of the two virtual prototypes. Under the new acquisition rules, the results of these computer-based logistics flyoffs would have equal weight with the results of cost and performance simulations in production contract decisions. Kate had guided the POET from its beginning as a research project in Pepamar's Simultaneous Imagineering Works a

few years earlier. The POET had already shown its mettle several times over the past year in Pepamar's business with the USAF Aerospace Logistics Centers (ALCs). The ALCs had become more important in military acquisition when the national strategy shifted from new systems to redesign and modification of existing systems. But Pepamar's future depended on POET's success with the MAV in the system upgrade market.

The Personnel Subsystem was an ancient concept from the previous century. Kate had come across it once in a dusty old textbook on System Engineering. It had to do with defining the role of people in operating and maintaining equipment, with designing machines to take human abilities into account, and with planning and managing the work force to assure the effectiveness and economy of a system over its useful life. In short, it meant including the performance of people when reckoning system performance.

The contribution of "human factors" to system effectiveness was well known back then. And everyone agreed that about 40 percent of life cycle costs of most military systems were in "human resources." Yet it was often hard to get industry designers and their government counterparts to pay much attention to people issues when new systems were being considered. Human-centered design was too hard and too expensive, it was said. The Personnel Subsystem eventually fell by the wayside. But now, thanks to a wise research investment strategy, new technologies like POET were creating a powerful human-centered design capability. And thanks to the emphasis now placed on people issues in the quality-minded acquisition ethos, the defense industry now placed a premium on human-centered design. The Personnel Subsystem was brought back.

Kate made a quick off-line inspection of the workstation's major subsystems to make sure they were all functioning properly. Everything checked out fine. She clicked on the main menu. The user interface language options appeared first: English, Japanese, and Pan-European. Kate clicked on the English option. The 30" high definition monitor displayed four menus down the left side, as well as a guide menu.



Kate clicked on the guide. POET's Corner was designed to function like an owner's manual, but to be understandable. An overview of the POET system scrolled into view. She accidentally toggled-on the disembodied voice, which read aloud in default Story Mode:

> **OVERVIEW:** POET will help you perform an accurate and thorough human-centered evaluation concurrently with engineering design. You are using a super-fast computer graphics workstation with ultra-expanded RAM capable of producing accurate, realistic simulations of people doing tasks. The workstation contains a number of tools that can help you discover, visualize, and document the maintenance tasks required for a given subsystem design and to describe their ability requirements - physical, perceptual, and cognitive. The POET-analyst has to know a good deal about human sciences because this technology only assists in task analysis. POET does not do the analysis itself or replace human expert judgment. Knowledge of firmware engineering is not needed, but you should know how to program in SONNETS, the POET's high-level AI language.

"Do you want to hear about the four workstation functions now?"

"Yes, please" Kate answered absent mindedly.

"Oh! Good morning Miss May!"

"That bug's still there! Or is it a virus?" Kate mused. She toggled-off the voice and read in silence.

> **Subsystem CAD Data Port** - Allows you to recreate computer-aided design (CAD) drawings on the display. You may telelink with external CAD machines that use the PDES standard or you may use the POET's electronic drafting board to input equipment geometry. You may work at the piece/part, subsystem, or system level of detail depending on your objective.
>
> **A Universal Work Unit Code (WUC) HyperBook** identifies all equipment groups in a hierarchical arrangement. This allows you to call up a drawing of, say, an engine (WUC Area 23XXX) in its installed state or components of the engine like the afterburner assembly (23ABF). You should have access to any engineering notations about the drawing.
>
> You may change the CAD geometry or other features of the proposed design any way you wish using the POET's CAD graphics software. This will allow you to portray and analyze human/machine problems as well as their solutions. Changes to CAD images are only "local." The Chief Imagineer has sole authority to change an officiai CAD drawing. Annotate a CAD drawing if there is a problem. But it is better to use the graphics simulation. That way the Chief Imagineer can view the problem and the proposed solution herself, and be persuaded. Seeing is believing, they say.

"DO YOU WANT TO SEE THE NEXT WORKSTATION FUNCTION?" "YES"

Human-Model/Task Analysis - This is the POET's soul. The workstation has a resident human-model that can be called up in different sizes and guises to interact with the CAD equipment renderings. The graphics simulation provides direct visual information about the physical, perceptual, and psychomotor requirements of proposed person/machine designs. There are, in addition, numerous aids to task description and analysis to enrich this visual task simulation technology. Let's look at all of these by opening up the submenus.

Instantiate Human-Model. A realistic-looking person is created from geometric modeling of basic skeletal "links." Special algorithms are used to enflesh this skeleton and to simulate clothing and other gear a maintenance person might wear. A 3-D illusion is created by color shading and related software artistry.

Define Body Type. The human-model can be drawn to accurately replicate the average physical dimensions of any target population or percentile gradations within that population. The workstation has current data on USAF maintenance populations internally which is used as the default anthropometry.

Strength Data Library. The average maximum force that can be generated by each population group in each of 12 common body postures for each of 40 common maintenance tasks is catalogued.

Tool Crib. The geometry, weight, and operational logic of the 9 standard hand tools authorized for U.S. Aerospace Force maintenance are stored here.

AGE Shed. All ten of the currently authorized Aerospace Ground Equipment (AGE) types are available for graphics imaging. These include the Multifunction Combat Turn Servicing Cart, the Engine Puller, and the IMIS Computer Support Vehicle.

Detailed Hand Model. For "close in" visualization of manual work, an anatomically exact hand model may be substituted for the polyhedral representation of the human-model's hands.

Vision Model. You may view the work environment as the human-model sees it or as an outside observer. The usual array of human-modeling graphics display technologies are also available with the vision model: any-angle perspective, "zoom," slow motion, and so on.

Team Work. The POET workstation can instantiate up to three human-models of any size who can be made to behave independently but cooperatively in simulating work tasks. This capability aids task design and is used to verify and document task crew size decisions, an important consideration in sizing maintenance manpower.

Animation. You can create realistic human movement simulations in several ways. The following metaphors can be mixed or used alone:

Automatic Transmission. The most common movements involved in USAF aircraft maintenance have been carefully studied and converted to "Crew Chief Notation." This is analogous to a choreographic score. It allows automatic task composition to be reduced to software code to drive a standardized body motion path and sequence. Variations in movement are not allowed and the animated sequence may appear unnaturally regimented. But for some task analysis purposes, such as predicting task times on highly proceduralized tasks, this may suffice.

Manual Transmission. Put on Data Gloves and you can move the human-model's hands and fingers as if they were your own. Kinematic motion transducers in the Data Gloves signal the human-model to move in the same way you move. This animation mode affords a realistic close encounter with the simulated task environment. This illusion can be enriched with other virtual experience technology for temperature, vibration, and pressure representation. For some simulated tasks, the POET's synthesizer can generate sounds that simulate the aural environment. When used with the vision model, the Data Gloves allow you to enter the human-model's virtual world and experience it at first hand. (No pun intended.)

Overdrive. The human-model can be made to perform discrete movements such as: reach with arms, turn head, sit, stand, walk, and pick up objects. In detailed hand modeling mode, a variety of common manual tasks for "knobs and dials" (operator) and "nuts and bolts" (maintainer) work can be portrayed. Fifty of these movements are stored as animation primitives. They are implemented through the speech synthesizer or keypad command macros.

Cruise Control. The POET can simulate an"intelligent" agent who appears to behave purposefully, naturally, and autonomously according to some logical plan of action. The agent will act and react according to user-defined "rule books" or AI planning models. The task environment must be carefully defined beforehand. The human-model will avoid errors (e.g.,walking in front of a running engine's air intake) and choose adaptive behaviors in logical order (e.g., remove cover before removing holographic head-up display).

Task Analysis Technology. When you have adequately simulated a maintenance task through some combination of the technologies discussed above, you are able to conduct and document a thorough "prescriptive" task analysis. Here are some of the human factors criteria that can be evaluated with the help of the embedded task analysis aids:

Task Design: Determining the right or best way of doing a task, given the current design constraints.

Job Design: Determining, across a whole system, how tasks should be grouped, and how task groups should be allocated to job specialists. Used best with the SUMMA Manpower Simulator.

Task Manning: Determining the minimum task crew size to carry out the work safely and efficiently. Important in human resource costing.

Task Time Line: Placing the task elements in logical, timed sequence and showing a whole task from start to finish, along with its relationship to other tasks.

Task Abilities: Determining the human abilities required to learn to do the task effectively. These include physical, psychomotor, and cognitive abilities. Some of these can be determined from visual inspection of task simulations. Others can be inferred with the help of the Design Advisor, who keeps a skills taxonomy for you.

Task Conditions: Specifying the tools and support equipment required, their manner of use, special safety considerations, and allowable variations in task procedures.

Task Prescription: Determining how a proposed design can be improved from a human factors point of view and simulating the effects of a proposed redesign. You may get help from the Design Advisor in cases where solutions are not obvious from direct visual inspection.

In sum, the POET's mc ive is to let you infer what the proposed work for a proposed design will be like by letting you see it. It allows you to do task analysis early, accurately, and thoroughly without costly physical mock-ups. If you can know what the maintenance work will be like early in design, before hardware is actually fabricated, you can help designers avoid costly mistakes. In so doing you will help reduce design development time and cost. But more, you can help make good designs into great designs by using computer technology to transform pedestrian task analysis into inspired POETry.

"DO YOU WANT TO SEE THE NEXT WORKSTATION FUNCTION?" "YES"

Design Advisor - This is an intelligently interactive array of human performance data stores. It consists of scientific facts, design standards, contract specifications, maintenance lessons learned, and detailed information about the USAF work force. The hypermedia technology allows this diverse knowledge base to be marshalled and presented in useful ways. The Design Advisor will help you make reasoned inferences about human task performance capabilities and limitations for specific design problems. It will help assure that you match workstation analysis results with formal contract requirements. The Design Advisor is on call through windowing software anywhere in the POET system. Some of the data stores and inferencing aides handled by the Design Advisor are:

Results of Meta-analytic Literature Surveys. This file displays summary statistics covering 120 of the psychological variables known to account for performance variation in 180 laboratory and applied tasks most relevant to military maintenance. These statistics are computed over the entire range of research studies ever published in the 136 journals sanctioned by the International Congress of Simultaneous Imagineers. The

rate of knowledge accumulation has increased markedly since original, empirical behavioral research was banned and efforts to unify the scattered knowledge base in the behavioral sciences were mandated instead.

Maintenance Data. The USAF Advanced Core Automated Maintenance System (CAMS) provides accurate and complete data on field experience with existing deployed systems. How often an item breaks, how it breaks, how long it takes to repair, and who repairs the item are all available through simple queries. Total Quality Management (TQM) goals for all systems, new or modified, are now tied to maintenance experience with systems already in use. In the past, logistics improvements were projected based on engineering theory or unaided expert judgment. Having real-world data on existing systems at hand will allow more accurate prediction of the logistics behavior of modified systems.

Knowledge Search and Rescue. The Design Advisor can quickly capture the state of knowledge applicable to any given human performance issue in human-modeling. The entire human performance data store is cross-indexed. Natural language query is supported. For example, the user may ask: "How many things can a person pay attention to at one time?" The Design Advisor may reply: "The answer used to be seven, plus or minus two. But it's less clear now. Whose experimental paradigm do you favor?" By entering into this Socratic dialogue, the user will easily discover what scientific knowledge has to say about a particular design evaluation issue.

"DO YOU WANT TO SEE THE LAST WORKSTATION FUNCTION?" "YES"

Logistics Data Port - If the CAD Data Port could be thought of as input, and the Human Modeling/Task Analysis and Design Advisor as data processors, then the Logistics Data Port could be thought of as the output. From this perspective, POET is an aid for:

Specifying Tasks:	Using CAD and human figure graphics technology.
Analyzing Tasks:	Using information automation for aided inference.
Documenting Tasks:	Using data management technology for human resource planning and for certain "downstream" analyses.

Both design influence and design documentation functions for maintenance are exhaustively covered by the Logistics Support Analysis (LSA) process through the Logistics Support Analysis Record (LSAR). The LSAR is vital for resource planning for weapon system support, including the "downstream" manpower, personnel, and training (MPT) or human resources planning functions. The interface is created by linking an LSA data model with the POET human-modeling technology.

The successful implementation of the Computer-Aided Acquisition Logistics Support (CALS) initiative in the last century eliminated paper-based documentation. CALS also achieved real economies in managing, updating, and distributing system support data, especially maintenance technical data, to the field. Human-modeling technology applied during

design can greatly expand the value and efficiency of CALS in our own century by providing more accurate and complete LSAR information on the human side of systems.

The Logistics Data Port in POET supports the following human resources analysis and documentation functions at the moment.

System Manpower Requirements. To use this simulation most effectively, you need to have manpower-relevant factors for the entire system under review. If you are looking only at individual subsystems, this simulation will give an incomplete picture. The simulation will project unit manpower requirements and costs using as input the task analysis information of crew size, reliability and maintainability (R&M) parameters, and system utilization rate. The embedded manpower simulator, called SUMMA, is created using object-oriented software technology. SUMMA operates in tandem with the Job Design module of the POET's Task Analysis Technology. Trade-off studies among job scope, equipment reliability, and manpower requirements can now be performed quickly and accurately. The entire manpower "data build" and simulation process for the MAV took just one person two hours. It used to take four people four months. This huge increase in software productivity has at last created a design interactive role for maintenance manpower. "Downstream" analyses for human resources have moved "upstream."

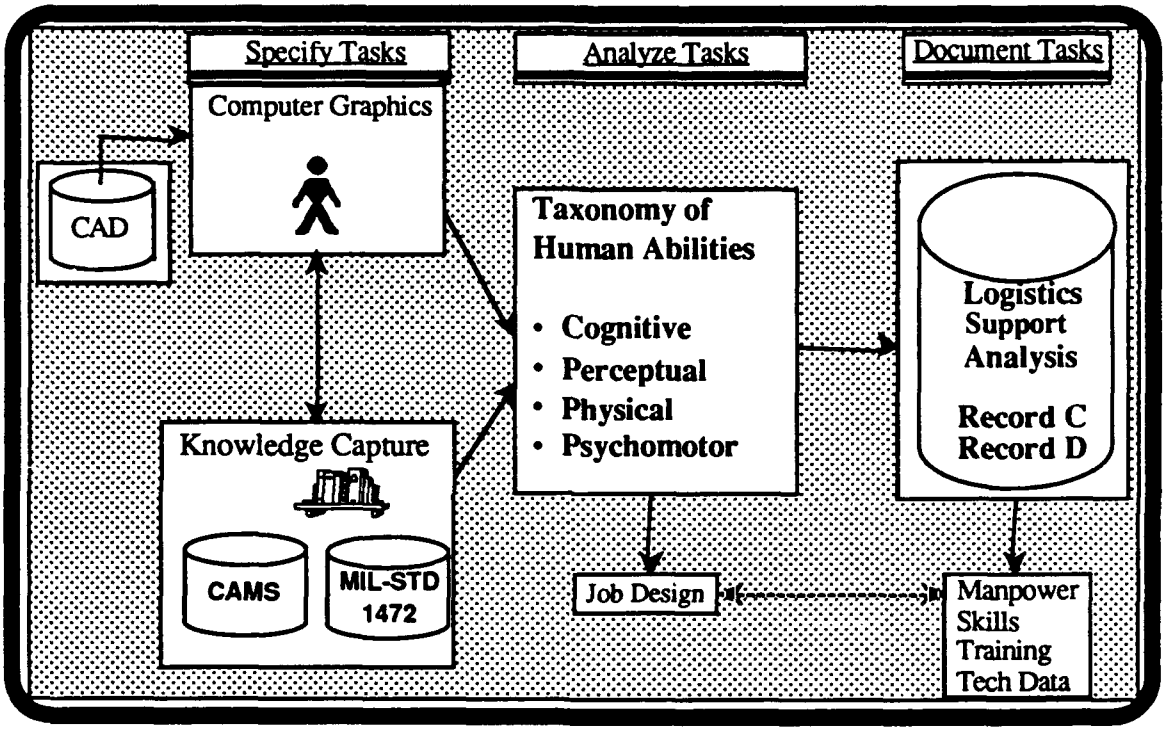
Training Development. The 3-D color workstation graphics are ideally suited to the 21st century CALS technical data mission. By using only the common fiber-optic/satellite telemedia and PDES standards, accurate and up-to-date maintenance graphics can be created for use in many locations for many training applications. For example, the data can be relayed to IMIS support vehicles on USAF flight lines across the globe, almost instantly, to keep maintenance tech data current with engineering changes. The task simulation graphics can be screen-dumped to compact laser disks or videotaped in hologram format for distribution from Air Logistics Centers to USAF technical schools, to on-the-job training sites, or to the new "Virtual Training Centers." Technical training for many maintenance jobs no longer requires the use of expensive prime equipment for "hands on" demonstration and practice. Computer graphics technology used in its place has made USAF training more effective, much less expensive, and much more abundant.

The POET hesitates to use hackneyed sayings, but the two key ideas for training are that a picture is worth a thousand words, and that you learn by doing. The Design Advisor does not equivocate in confirming these ideas, although his language can be more professorial. He might say that an emergent cognitive structure with synergistic potential is created when high-fidelity instructional stimuli are presented through the visual and psychomotor modalities simultaneously.

LSAR Data Management. All task description and task analysis data applicable to Personnel Subsystem definition are automatically written to ASCII files for upload to the LSAR. This MIL-STD 1388-3D data system, now available much earlier in the design cycle, provides a complete, authoritative repository of current, validated logistics information. There is no paper, no lost data, and no updating problem. Data management

costs are reduced, and planning for system maintenance and support by Air Logistics Centers is vastly improved. Because the LSAR data base is under TQM protection, it is available for human-centered analysis for all redesign opportunities created by system modifications, upgrades, and mission changeovers. Of course, major new systems will benefit from better LSA data management too, though these applications are admittedly not as glamorous or important.

"DO YOU WANT TO SEE THE OVERALL POETIC VISION?" "YES"



"LEAVING POET'S CORNER NOW. RETURNING YOU TO MAIN MENU."

"DO YOU WANT A CURRENT EVENTS UPDATE ON THE WAY? " "YES"

****** News Wire**	Pepamar refuses Trump's request for POETic license. Trump offers 14 billion Euroyen in buyout attempt.
****** Weather Vane**	Raining cats and dogs tonight. Humane Society overwhelmed with calls. Moonshine toward daybreak.
****** Sports Desk**	Yankees defeating Reds by tie score, 2-2. Washout. Trump announces Yankees will move to New Jersey.

Kate ignored the news. She was already configuring the workstation for Demo Mode. She wanted to rehearse tomorrow's CDR presentation. The screen dimmed slightly during the brief moment it took to load the laser-graphics Data Pack. But everything seemed to be working fine.

Kate navigated through the POET's visual and verbal reports for each subsystem of the MAV. She used the Work Unit Code HyperBook to identify equipment and maintenance tasks. She didn't notice the hours passing. Kate had been told that the people from Orchard would be especially interested in the Personnel Subsystem definition for the MAV's propulsion subsystem, so she called up the Engine Sector for detailed review.

The workstation produced animated 3-D color graphics of engine maintenance tasks as Kate rattled off "action-object" keypad commands defining flightline maintenance work. She stopped the displays after a while and ordered the human supportability Warnings and Cautions Report for the engine. The screen went blank for a moment. The thought of computer infection briefly entered her mind. Then --

Engine Warnings & Cautions Report

1. Engine remove/replace task needs four people, any ability group. But contract specification requires three people. Design Advisor counsels redesign of Engine Puller AGE. Two people could do this task with greater use of robotics. Manpower impact is 4 percent overall reduction in human resources life cycle cost. Feasibility of Engine Puller redesign not known. Mechanical Engineering CAD cell notified of opportunity.

2. Relocate bore scope port to accommodate 5th percentile female stature. Result: Ladder AGE will no longer be needed for inspection task. Task time reduced 40 percent, confirmed by graphics resimulation. Combat quick-turn time reduced 15 percent, now = 14 minutes.

3. Engine duct work found to interfere with maintenance of synfuel pump. Adds 2.5 hours to any pump maintenance action because duct work must be removed for access. Reliability and Maintainability team projects high frequency of maintenance and lengthy repair time. Task Design Module projects three people, two different specialists. Prescription: Place pump on outside. Result: Structural repair specialist is no longer needed. Two people needed, 5th to 95th percentile body size. Eliminate 2.5 hour "time tax" on pump maintenance. SUMMA Manpower Simulation shows 3 million Euroyen cost avoidance in MAV human resource category through this simple design change. Greater R & M expenditure on synfuel pump design is now justified. Chief Budgeteer notified.

4. Color-coded built-in test warnings on diagnostic panel cannot be discriminated under glaring desert sun conditions or when wearing chemical defense visor. This may lead to catastrophic engine failure. Prescription: Design Advisor recommends positive switch with redundant iconic display instead of unaided color codes. Hard copy Lessons Learned narrations and human factors literature citations for CDR discussion are available at Data Store Checkout Counter.

5. The afterburner synfuel injector assembly appears to have mysterious failure modes that cause simulated maintenance persons to engage in "superstitious" and other maladaptive maintenance actions. They either give up entirely or else change out assemblies regardless of the reported fault. Cognitive mark-up on injector assembly work indicates need for high tolerance of ambiguity and heuristic decision making skills. These personnel skills far exceed the projected talent budget. Design Advisor is perplexed. Prescription: Maturational testing of injector assembly to fully reveal all failure modes and permit proceduralization of all maintenance tasks. Else enroll mechanics in Harvard Executive Development Center.

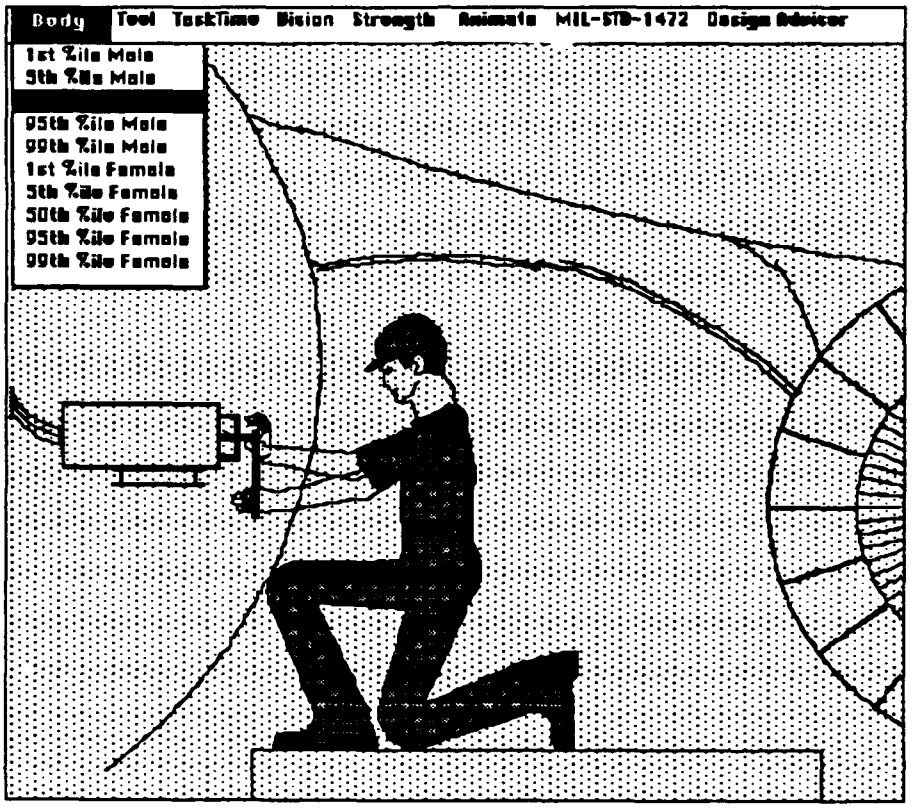
Kate suppressed the rest of the engine report and went on to the MAV total supportability summary. This would show the big picture on human aspects of MAV performance.

MAV Big Picture

Maintenance Human Resources	**4 spaces per MAV**
Human Factors Problems Found	**345**
Human Factors Problems Solved	**345**
MAV Design Development Time	**6 months**
MAV Design Cycles	**17**
Cost Avoidance Using POET	**435 million Euroyen**
Cost of POET Application	**.3 million Euroyen**
Combat Capability Value Added	**2 more sorties per day**

Kate was satisfied. The POET had performed eloquently. Her only worry now was the POET's speech synthesizer. But that could be toggled-off. Kate looked out to the parking lot. Above, a sea breeze chased the last of the storm clouds from the starlit sky. Below, white moons danced in reflected merriment on the black rain puddles. "A thousand points of delight," Kate beamed. Tomorrow would be a beautiful day in every way. "Guess I'll call it a night, or a morning, actually" she yawned alarmingly at the clock. It was 4 A.M. Kate took one last look around the room. Everything in order. The workstation switched itself to Standby Mode. Kate turned off the lights and heard the door close behind her. She did not hear the disembodied voice in the darkened room.

"Good morning Miss May."



Golden sun greets silver strand
Zephyr's arms embrace the land
Rousting storm-tossed reverie
Morning wakes and smiles on thee.

- Eboly